Development of the Liquid Projectile Weapon

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1.0 INTRODUCTION

UTD Incorporated has performed development work on a an innovative concept for a limited effect (LE) weapon. UTD's concept will launch a slug of liquid a fraction of an inch in diameter, several feet long with sufficient momentum and kinetic energy to inflict a sharp pain at ranges of 50 or more feet, but will not penetrate the skin or cause permanent injury. Dyes and/or scents can be incorporated to mark an individual. UTD envisions two versions: a 3 or 4 shot system with integral magazine and a multiple shot system using a backpack. Both will be self cycling. Energy to fire the liquid slug will be from compressed gas.

1.1 Background

The Liquid Projectile Weapon was originally conceived by UTD in 1995 in response to a percieved need for new limited effect anti personnel weapon technologies. To date, UTD has developed the technology and performed experiments which conclusively prove its feasibility. This work continues to be the subject of an ongoing Internal Research and Development (IR&D) program in which UTD has conducted engineering research, built a Proof of Principle mock up, and performed physical experiments, proving the viability of the concept and demonstrating it to practitioners.

1.2 The Need

A capability gap currently exists in the spectrum of force available to corrections and law enforcement professionals. Table 1 contains a comparison of the capability offered by UTD's Liquid Projectile Weapon concept and other devices presently available. The Liquid Projectile Weapon fills the region bounded by Tasars and pepper (oleoresin capsicum) sprays, effective to only 12 or 15 feet, and the lower limit for ballistic LE devices such as rubber bullets, stingballs, stingbags, and wooden baton skip weapons which become dangerous up close. The Liquid Projectile Weapon will operate in the 0 to 50 or more foot range, filling an existing capability void.

Table 1. Comparison of Options to Capture and Restrain an Individual.

Device/Technique	Range, ft	Physical Effect	Risk*	Remarks
UTD Liquid Projectile Weapon	0-50	Pain, Incapacitation	Low	Can contain marking dyes, irritants, scents, variable power
Voice	0-50	none	Low	Preferred whenever possible
Fists	0-3	Pain, Incapacitation	High	Least preferred, highest probability for injury
Stick/Baton	0-5	Pain, Incapacitation, Injury	High	Most common
Pepper Spray	0-15	Pain, Incapacitation	Med	85% effective, must have face/eye shot
Existing LE Ballistic Devices	60-150	Pain, Incapacitation, Injury	Low	May cause serious injury or death at CLOSE range.
Handgun	2-100	Incapacitation, Serious Injury, Death	Low	With conventional ammunition. High potential to injure innocent bystander
Hand Held Electrical Stun Devices	0-5	Incapacitation	High	Must be in physical contact with suspect
Air Tasar	0-12	Incapacitation	Med	86% effective, only a single shot device

* Physical Risk to Officer using Device or Technique

and understanding of physics and mechanics often leads to a technology breakthrough. The Liquid Projectile Weapon concept is the product of several UTD brainstorm sessions in the LE weapon area. Early studies led to the conclusion that a long, thin liquid slug used as a "bullet" had the following fundamental advantages. Features and benefits of a developed Liquid Projectile Weapon are summarized in Table 2.

- *The degree of lethality should be independent of range provided the slug was launched at a proper velocity and assuming the target was hit on any part of the body except the eye.*

- *The weapon would be simple. Liquid, driven by gas with a piston between the two media, could be ejected through a nozzle, with the use of a simple valving system.*

- *The liquid slug could be used to carry energy to a target, causing a painful diversion of attention. It could be used as well to carry an identifying dye or an irritating agent.*

- *The weapon could be carried as a sidearm, with automatic firing capability. The number of "shots" carried would depend on the mission and could range from a single shot upward, there being about 24 shots available from each gallon of liquid available.*

The Liquid Projectile Weapon will be a simple device. Our Proof of Principle hardware had only two moving parts. This hardware is constructed of stainless steel components and uses conventional buna rubber O ring seals. A production version might be made from aluminum or other material.

A Liquid Projectile Weapon with an integral 3 shot magazine is a natural to physically deter unlawful behavior at ranges from 0-50 or more feet. The ability to engage an assailant beyond the "...critical 7 foot radius" is particularly desired. Unlike other LE ballistic devices, the Liquid Projectile Weapon will be nonlethal at close range. Unlike Tasars or electrical stun devices, the Liquid Projectile Weapon will be effective at ranges over 15 feet. The Liquid Projectile Weapon will be effective both for advancing and retreating targets, unlike pepper sprays which require a clear face shot. Marking and physically stunning individuals without concern as to closeness is the principle benefit during civil disturbances. Unruly individuals at civic demonstrations can be marked, and thus not be able to "melt into the crowd" after throwing bottles or assaulting officers.

The Liquid Projectile Weapon is particularly suited to corrections where arrestees, prisoners, or individuals may become violent or uncooperative. A Liquid Projectile Weapon with an integral 3 shot magazine would be useful to quell small disturbances. A larger capacity backpack version will work well for riots.

Table 2. Features and Benefits of UTD's Liquid Projectile Weapon.

Feature	Benefit	Payoff
Functions as an impact device.	Delivers a strong blow to stun target.	Stun and subdue a person without lethal effects.
Ammunition = pure water.	No clean up: projectile disintegrates on impact.	Projectile can not be used against guards.
Less than Lethal at all ranges.	Better utility in close quarters with minimum liability risk.	Eliminate litigation and settlement costs for prison guards and police officers.
Compressed gas energy source.	Can be stored within prison walls.	Readily available to quickly quell disturbances.

UTD conducted only limited evaluations of the weapons precision or repeatability. We found the it to be adequte, and at one point had 12 consecutive shots at a 33 foot range fall within a 3.5 inch radius which we considered adequate for a close in weapon.

4.0 DEMONSTRATION

The Liquid Projectile Weapon launcher was then mounted on a modified rifle stock. UTD completed detailed impulse-momentum calculations to determine the assembled version's recoil, and found it to compare roughly to a 12 guage shotgun. We conducted over 100 hand held firings including demonstrations around the country for persons in law enforcement, military special forces, corrections, and SWAT.

The response of the user community has been positive. UTD made a short video tape and executive brief which has been distributed nationwide. UTD presented the Liquid Projectile Weapon to attendees of the American Jail Association Conference Session on Less-than-Lethal technology in May of 1997. This gave practitioners the opportunity to see and fire the Liquid Projectile Weapon. It was unusual that every practitioner who has seen the Liquid Projectile Weapon thinks it is a great idea, immediately envisions how it could be used, and understands its benefits. User comments are summarized in Table 3, below.

Table 3. Summary of Practitioner Comments.

User / Scenario	Summary of Practitioner Comments
Prison Extraction Team	Prison guards often encounter inmates who barricade themselves in their cells. Pepper sprays are often ineffective as inmates will cover or turn their faces, leaving guards no option but to enter the cell and physically remove them. This subjects both guards and inmates to injury and liability claims. In contrast to cartridge propelled devices, the Liquid Projectile Weapon can be stored "within the wall," i.e. on prison grounds - since it is powered by compressed gas, instantly available when needed.
Prison Yard & Mess Hall	There is no chance that the Liquid Projectile Weapon's liquid bullet will ricochet and strike an unintended target. There is no clean up when used with water ammunition - just let it evaporate. Adding dye will permit easy identification of instigators who might otherwise escape punishment in the confusion of the moment.
Jails	Sheriff departments are always looking for new options to deal with unruly prisoners, marking and physically stunning unruly inmates at close range within a confined space or cell with no smoke or excessive noise were viewed as advantageous.
SWAT Team	The Liquid Projectile Weapon is LE at all ranges. Current LE ballistic weapon restrictions for minimum range are unrealistic when entering a barricade situation. SWAT Teams simply will not accept a LE weapon with a range restriction: they would rather use conventional weapons. The capability offered by the Liquid Projectile Weapon would reduce the risk to perpetrators and victims during domestic disturbances during which an otherwise law abiding person threatens officers while under the influence of intoxicants.
Civil Unrest	Many LE devices present a risk to users - pepper spray projectiles can be picked up and thrown back at officers or guards. Pepper based products often have restriction based on the space's ventilation. The Liquid Projectile Weapon's liquid slug disintegrates at ranges over 100 feet, and thus poses no threat to innocent bystanders.
Military Peacekeeping	The Liquid Projectile Weapon can be used to control crowds around food, water, dispensing areas where hungry indigents may form an unruly mob. The Liquid Projectile Weapon can be used to keep people at a distance without inflicting serious harm, reducing the "CNN [Cable News Network] factor" or adverse publicity associated with killing or seriously injuring noncombatants.

5.0 SAFETY AND LIABILITY

Current LE ballistic weapons work well at the intended stand-off distance, but at close range they become deadly, and cannot be used without great risk. Existing LE weapons' projectiles strike a target all at once, whereas the liquid slug will interact over a longer period. For example, a 3 foot liquid slug traveling at 300 ft/sec will impact over (3 ft/ 300 ft/sec) = 0.01 second. Compared with a Defense Technology 12 Gauge bean bag, which weighs 1.44 oz and is fired at 280 ft/sec, assuming it penetrates less than 44 mm (the limit of human body penetration for bullet proof vests) with constant deceleration (conservative), the interaction time is ((½) 44 mm/304.8 mm/ft/280 ft/sec) = 0.00103 seconds. Both collisions are fully inelastic, so all kinetic energy goes into deforming the target and/or viscous or visco-elastic deformation of the projectile, but the rate at which a liquid slug's kinetic energy is converted to heat and target deformation is far lower than that of existing LE weapons. The Liquid Projectile Weapon slug weighing 0.3 lb moving at 300 ft/sec will have about 419 lb-ft of kinetic energy, that will dissipate at an average rate of (419 lb-ft/0.01 sec) = 41,925 lb-ft/sec during impact. A 1.44 ounce bean bag LE round will have a kinetic energy of 109 lb-ft at 280 ft/sec, which will be dissipated at an average rate of (109 lb-ft/0.00103 sec) = 105,825 lb-ft/sec - over 2.5 times greater. Liquid Projectile Weapon impact forces are therefore less, as depicted in Figure 3.

The liquid slug loses less speed per distance traveled than a typical LE ballistic projectile. Current LE ballistic projectile velocities drop sharply with range. The projectile's velocity must be high enough at the muzzle to be effective at a distance. The high initial velocity makes these devices lethal at close range, whereas the liquid slug "muzzle velocity" can be engineered for the desired effect at close range, knowing it will be almost the same at a distance. For example, a LE ballistic projectile, shot either from a 37/38 mm gas gun or 12 gauge shot gun, will have an aspect ratio between 1:1 or 1:3. The blunt shape will decelerate quickly from aerodynamic drag. The liquid slug has an aspect ratio of (0.5 in / 36 in) = 1:72. As shown in Figure 5, the liquid slug loses little velocity per distance traveled since the ratio of aerodynamic drag to total kinetic energy is less.

The liquid slug, which is projected at a stagnation pressure of several hundred PSI, will not penetrate the human skin. We surveyed the considerable amount of research done on the dangers of high pressure liquid jets operating at pressures IN THE TENS OF THOUSANDS OF PSI where pressurized liquid sprays are used paint stripping, tank cleaning, and diesel engine fuel injectors. High pressure liquids with abrasives are used to cut materials such as composites, metals, wood, and rock. Two journal articles in particular were of interest: one a Japanese researcher (Katakura, et al) who has conducted experiments of

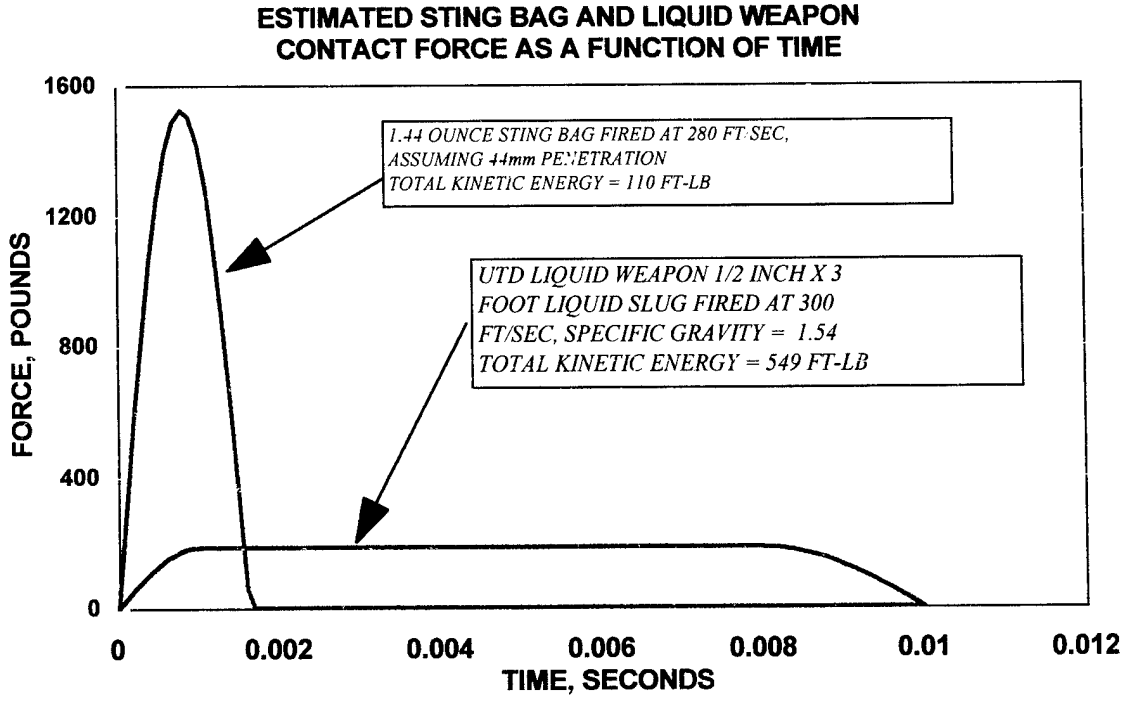

Figure 3. The Liquid Projectile Weapon is Fundamentally Safer Since the Impact Duration is Longer, Resulting in Lower Contact Force.

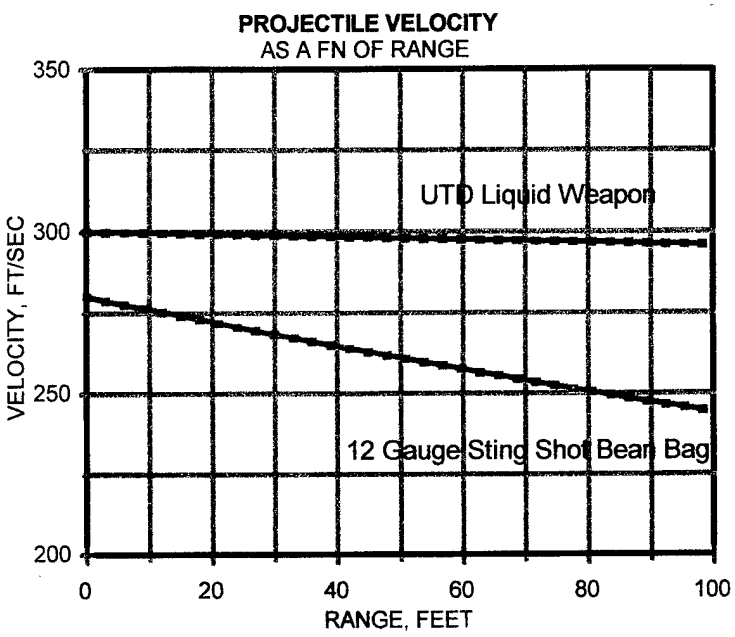

Figure 4. The Liquid Slug Loses Less Velocity than a Typical LE Round.

high pressure liquid streams with ox skin, which is very close in strength to human skin. Dr. Katakura proved that a liquid stream pressurized to the same value as the Liquid Projectile Weapon requires a concentrated stream for 10 to 25 seconds to pierce skin. The Liquid Projectile Weapon slug will interact with a target for about 1/100th of one second, clearly indicating its inability to penetrate skin. The foregoing information strongly suggests that the Liquid Projectile Weapon will be intrinsically safe for use on human subjects in both an absolute sense and relative to other LE ballistic devices.

6.0 CONCLUSIONS

UTD has proven the feasibility of the Liquid Projectile Weapon concept. We believe its development and distribution will provide a needed option for the law enforcement and corrections professional.